FINAL Report

New York State Integrated Pest Management Projects in Agriculture, 2012 ***Vegetables Research and Development***

Altering Planting Configurations to Manage Bacterial Bulb Decay in Large-Scale Onion Production

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Abstract:
Bacterial diseases of onions have become a serious threat to the sustainability of the New York onion industry. Losses up to 40% can occur as a result of reduced onion quantity and quality. Ultimately, an Integrated Pest Management (IPM) approach will be required to manage bacterial diseases of which cultural practices will be important components. Recently, studies with small-scale production of onions on plastic mulch showed that when plant spacing was reduced from 6" or 8" to 4", this provided 53 to 64% control of bacterial bulb decay at harvest. Marketable yield also increased by 1.4 to 2.4 times due to more marketable jumbo-sized bulbs. Wide plant spacing produced big bushy plants with more leaves, thicker necks, delayed maturity and bigger bulbs, and it was these bigger colossal-sized bulbs that rotted. By narrowing plant spacing, having significantly more healthy jumbo bulbs more than made up for fewer colossal bulbs. Whether reduced plant spacing also reduces bacterial bulb decay in direct seeded onions that are already grown at high plant populations warranted investigation. The purpose of this project was to evaluate the effect on bacterial bulb decay and yield of plant and row spacing, and bulb area in large-scale production of direct seeded and transplanted onions. An on-farm small-plot research trial was conducted using transplanted onions (c.v. Canady) and included 13 planting configurations. Plant size and maturity trends were generally opposite of what was found previously in studies with small-scale onion production: in this study, plant height, number of leaves per plant and maturity generally increased as plant population increased. Despite this, yield and bulb size distribution were similar to previous results. There was a general trend that total yield, boiler, small and medium sized bulb weight, and economic return increased as plant population increased. Within each row spacing (15", 10" and 7.5"), these parameters increased as the plant spacing decreased from 8" to 6" to 4". Although less dramatic, within each plant spacing (4", 6" and 8"), these parameters increased as row spacing decreased from 15" to 10" to 7.5". Generally, yield increased as plant population increased because there were more bulbs per area to contribute to yield. Our data suggests that plant spacing is a stronger predictor of yield and bulb size than row spacing or bulb area. Bacterial bulb decay 9 weeks after the onions were pulled from the field ranged from 0.8 to 3.6% incidence and no significant differences occurred among planting configurations. There were no significant correlations between incidence of bacterial bulb decay and plant size, maturity, yield and bulb size distribution. There was no relationship between bacterial bulb decay and plant population. Repeating this study is certainly warranted in order to generate robust data from which to make recommendations for planting configurations to manage bacterial diseases in large-scale onion production.

Background and Justification:

Bacterial diseases of onions have become a serious threat to the sustainability of the New York onion industry. Losses up to 40% can occur as a result of reduced onion quantity and quality. In 2011, one grower family in NY reported that they reduced their onion acreage from 175 acres to 100 acres due to annual losses of 20 to 35% from bacterial bulb decay. Another grower stopped growing red onions from transplants, because high levels of bacterial problems made this once lucrative crop, unprofitable. Management of bacterial diseases of onions is a high research priority for both NY-IPM and the Onion Research and Development Program, as there are few effective management strategies.

New York is the largest producer of onions in the Northeastern U.S. accounting for 97% of the production, with approximately 10,000 acres and an annual average value of 51.8 million dollars. Onions are plagued by several bacterial pathogens that cause bulb decay in NY, including *Burkholderia cepacia*, *Pantoea ananatis*, *P. agglomerans* and *Enterobacter cloaceae.* Because bacterial bulb decay often affects only a single internal bulb scale while the outer scales remain firm, such infected bulbs are virtually impossible to detect. When such onions are shipped and consequently rejected, this often results in entire loads being dumped, despite only a small percentage of bulbs being infected, which results in significant economic losses.

Ultimately, an Integrated Pest Management (IPM) approach will be required to manage bacterial diseases of onions, which could involve field sanitation, tolerant varieties, induced resistance materials and bactericides, crop rotation and cover crops, soil amendments, altered planting configurations, reduced nitrogen fertility, strategic curing conditions and imaging technology post-harvest. Researchers and Extension professionals at Cornell have been working on several of these components. Recently, studies conducted by Hoepting *et al.* (2009, 2010) with small-scale production of onions on plastic mulch showed that when plant spacing was reduced from 6 or 8 inches to 4 inches with 3 or 4 rows per 3-foot plastic mulch bed (row spacing: 4 rows = 6"; 3 rows = 8"), this provided 53 to 64% control of bacterial bulb decay at harvest. Marketable yield also increased by 1.4 to 2.4 times due to more marketable jumbo-sized bulbs. Wide plant spacing produced big bushy plants with more leaves, thicker necks, delayed maturity and bigger bulbs, and it was these bigger colossal-sized bulbs that rotted. By narrowing plant spacing, having significantly more healthy jumbo bulbs more than made up for fewer colossal bulbs.

It is very likely that using the cultural practice of narrowing plant or row spacing or reducing the area per bulb would also reduce bacterial bulb decay for large-scale production of onions. Our results from small-scale production suggest that bacterial bulb decay decreases when planting area per bulb is less than 36 inch^2, and continues to decrease as bulb area decreases. This could explain why there is often higher incidence of bacterial bulb decay in wider spaced transplanted onions (15" row spacing x 4" plant spacing = 60 inch^2 /bulb) than in closer spaced direct seeded onions (15" row spacing x 1.7" plant spacing = 25.5 inch^2 /bulb) of the same variety. Whether reduced bulb area impacts bacterial bulb decay in direct seeded onions that are already grown at high plant populations is unknown. Our results from small-scale production also suggested that row spacing may be a very important factor related to bulb decay: when row spacing increased from 6 inches (4 rows/bed) to 8 inches (3 rows/bed), incidence of bacterial bulb decay at harvest increased 2 to 4 fold for each plant spacing (4", 6" and 8"). Investigation of the effects of bulb area, and plant and row spacing on bacterial bulb decay and yield of both direct seeded and transplanted onions in large-scale production is warranted. This also addresses the high NY-IPM research priority for multiple vegetable crops, "preventative measures for disease control such as rotation, cultural practices and avoidance".

Objectives:

1. Evaluate the effect on bacterial bulb decay and yield of plant and row spacing, and bulb area in large-scale production of direct seeded and transplanted onions.

2. Evaluate in the short-term large-scale growers' plans to adjust their onion planting configurations to reduce bacterial diseases and increase yield in 2013.

Procedures:

Objective 1: An on-farm small-plot research trial was conducted using transplanted onions of a sweet onion variety that is known for having bacterial issues, "Candy". Onion grower, James Panek, Panek Farms, hosted the trial on his farm in Albion, NY on mineral soil. The trial was arranged as a complete randomized block design with 13 treatments and 5 replications. Each replicate plot consisted of an area one bed wide (5 feet) by 5 feet long. Ten transplanted onion planting configurations were evaluated including two grower standards (4 rows/bed = 15" row spacing with 4" plant spacing & 4 rows /bed alternating 10" and 20" row spacing with 4" plant spacing) and 5 (= 10" row spacing) and 7 (= 7.5" row spacing) rows per bed, each with the standard plant spacing (4") and 6" and 8" plant spacing, for a range of areas per bulb from 30 to 120 inch^2, and plant populations from 55,272 to 209,088 plants per acre. Also, three direct seeded planting configurations were also evaluated including the standard (4 rows/bed = 15" row spacing & 6 seeds/foot, plant population = 278,784 plants/acre), a higher seeding rate (8 seeds/foot) with 4 rows per bed, and the standard plant population but with 7 rows per bed and 4 seeds per foot. Table 1 shows the treatment details.

The planting configurations were set up by hand using custom fabricated hole-poking tools and bare root onion transplants provided by Panek from Sunbelt, Phoenix, AZ, were planted by hand on May 14. Panek maintained the trial as he did the rest of his onion field, which included pivot irrigation. The average daily temperature was 62, 68, 74, 70 and 61 ◦F and the total monthly rainfall was 2.1, 4.6, 1.5, 3.7 and 3.5 inches for May, June, July, August and September, respectively. Although the crop was off to a great start, during the month of July, it did not size up normally. The exact cause of the stunted growth in this field was not determined, but likely partially due to the late planting and very dry month of July.

The number of leaves per plant, height of the tallest leaf per plant and neck diameter was quantified on 10 randomly selected plants per plot on June 13 and July 13. Percent lodging was visually estimated on August 10. Once all of the onions lodged, all of the onions per plot (5 ft x 5 ft area) were pulled on September 4, removed from the field and windrowed for 9 weeks in a sheltered area, then topped, and weighed by grade on November 6. Standard bulb sizes included <1.75", 1.75-2.25", 2.25-3" and >3" for boiler, small, medium and jumbo sized bulb classes, respectively. Bulb decay was detected by squeezing each bulb. The total number of bulbs harvested was compared to the target plant population, and if the two differed by more than 15%, the harvest data was discarded from these replicates. Total economic return was calculated on a per replicate basis and averaged across replicates. The yield and bulb size distribution data from the trial plots was extrapolated to a per acre basis. Average prices for yellow cooking onions were used for the different bulb size classes, which were provided by the grower cooperator. They were $6, $10, $16 and $20 per cwt for boiler, small, medium and jumbo sized bulbs, respectively.

Differences among treatments were analyzed using a General Analysis of Variance (ANOVA) and means separated using Fisher's Protected Least Significant Difference (LSD) test (α=0.05).

Objective 2: It was our intention to invite onion growers and other allied industry members to view the trial, either on their own (trial information available on site) or as part of a twilight meeting in early August, so that they could see for themselves the effect of planting configurations on bacterial decay and yield. Unfortunately, during the month of July, the onion crop in our grower cooperator's field exhibited severe stunting in large patches. The field did not look good and we did not want to invite the onion industry to look at our trial at the expense of them seeing our grower cooperator's poor onion crop. The onions in our trial also did not size up normally, so under these circumstances, we felt it best to not showcase the trial.

During the fall and winter, we planned to summarize and present the results from this trial to onion growers in a newsletter article or as a direct mailing, and during the winter at the New York Onion Industry Council Meeting. After exposing large-scale onion growers to the results of this study, we wanted to follow up with them to gauge their interest in and possible plans to experiment with planting configurations on their own farms in 2013. However, with such low incidence of bacterial bulb decay, lack of significant differences among treatments and poor yields from our trial, we decided to hold off on sharing the results of this trial with growers until after the trial is repeated and results obtained under higher disease pressure.

Results and Discussion:

<u>Plant Size (Table 2):</u> Significant differences among treatments occurred for plant height and number of leaves per plant only on June 13 where the tallest (26.8 cm) and shortest (23.2 cm) plants differed by 3.6 cm, and the most (5.9) and least (4.9) number of leaves per plant differed by 1.0 leaf. In general, the highest density planting configurations with 22.5 and 30 inch^2/bulb had the tallest plants with the most leaves, which may be a function of increased plant to plant competition. On June 13, treatment #10 (7.5" rows, 8" plant spacing = 60 inch^2/bulb) and treatment #3 (15" rows, 6" plant spacing = 90 inch^2/bulb) also had some of the tallest plants and most leaves per plant in the trial. Generally, the shortest plants with the fewest leaves per plant occurred in the planting configurations with 10" rows (treatments #5, #6 & #7). Treatment #1 (grower std: 10-20" rows, 4" plant spacing = 40-80 inch^2/bulb) had the shortest plants in the trial on June 13, which in addition to treatments #5, #6 and #7, was not significantly different than treatment #2 (grower std: 15" rows, 4" plant spacing = 60 inch^2/bulb) and treatment #9 (7.5" rows, 6" plant spacing = 45 inch^2/bulb). Significant differences did not occur among planting configurations on July 13, although similar trends as those observed on June 13 occurred. Differences in neck diameter from the largest and smallest plants were 0.9 mm and 1.3 mm on June 13 and July 13, respectively. No significant differences among planting configurations occurred, although on July 13 the highest density planting configurations with 22.5 and 30 inch^2/bulb had the smallest necks, while the lowest density planting configuration with 120 inch^2/bulb had the widest necks.

Our studies in planting configurations with small-scale onion production showed that as plant to plant or row spacing increased, plants had more leaves with thicker necks, which is generally the opposite of what we found in this study. When this trial was planted, it was noticed that there was a lot of variability in the size of the individual bare root transplants with respect to both stem diameter and number of leaves per plant. A labor crew helped us to transplant the trial, and thus, more variability may also have been introduced by the different planters as some people just drop plants into the pre-poked holes, while others press them in ensuring good root to soil contact. These types of confounding variables should be considered and minimized or eliminated in future trials.

<u>Target Plant Population (Table 3):</u> Harvest data from reps 1, 2 and 3 in treatment #3 and reps 4 and 5 in treatment #11 were discarded because they deviated from the target plant population by more than 15%. After discarding these replicates, treatment #3 had 100% of the target plant population per plot and no other treatment was significantly different from this treatment.

<u>Maturity (Table 3):</u> No significant differences occurred among planting configurations for maturity, which ranged from 40 to 77% lodging on August 10. Treatment #4 (15" rows, 8" plant spacing = 120

inch^2/bulb) was the most mature despite having the lowest planting density. A general rule of thumb in onions is that as plant population increases, maturity hastens due to plant to plant competition. In this trial, the opposite occurred. For example, within the 15" row spacing configurations, maturity advanced as the plant spacing increased from 2" (52% lodging) to 4" (61% lodging) to 6" (64% lodging) to 8" (77% lodging). Similarly, for the 6" plant spacing, maturity advanced as the row spacing increased from 7.5" (40% lodging) to 10" (54% lodging) to 15" (64% lodging). The 4" plant spacing configurations also followed this trend. Among the three treatments with the same bulb area of 60 inch^2/bulb, treatment #10 (7.5" rows, 8" plant spacing) had the most advanced maturity followed by treatment #2 (grower standard: 15" rows, 4" plant spacing) and then treatment #6 (10" rows, 6" plant spacing). Treatments #11 (15" rows, 1.5" plant spacing = 22.5 inch^2/bulb) and #10 (7.5" rows, 8" plant spacing = 60 inch^2/bulb) oddly matured at the same rate (66% lodging).

Assuming that fertility is not a limiting factor, than the individual plants in lower plant population treatments theoretically could have more nutrients per plant, which can delay maturity, because vegetative growth is stimulated with high fertility, or, plants grown in high fertility lodge sooner, theoretically because the top growth gets so big that the neck cannot support the plant to stand upright anymore. Although the leaf height and number data do not suggest that the lower plant populations had the larger plants, neck diameter tended to increase as plant population decreased. In this study, the entire field of onions was undersized, which may have been a function of its later than ideal planting date and very dry growing conditions during July; perhaps under more normal growing conditions, results would have been different. Soil and tissue samples were not analyzed for nutrient content.

<u>Yield (Table 3):</u> Total marketable yield ranged from 167 to 440 cwt/A, which is below the New York State average of 450 cwt/A, and transplanted onions should yield even higher. Significant differences occurred among planting configurations for total marketable yield. There was a general trend that total yield increased as plant population increased with the two treatments with 22.5 inch^2/bulb (#11 & #13) having the highest yield (440 cwt/A), which was not significantly different than the two treatments with 30 inch^2/bulb (#12 & #8). Within each row spacing (15", 10" and 7.5"), total yield increased as the plant spacing decreased. Although less dramatic, within each plant spacing (4", 6" and 8"), total yield increased as row spacing decreased. Among the three treatments with the same bulb area of 60 inch^2/bulb, treatment #10 (7.5" rows, 8" plant spacing) had the highest yield, which was not significantly different than treatment #2 (grower standard: 15" rows, 4" plant spacing), but was significantly higher than treatment #6 (10" rows, 6" plant spacing). There was no difference in total yield between the two grower's standard planting configurations. Total yield increased as plant population increased because there are more bulbs per area to contribute to yield.

<u>Bulb Size Distribution (Table 3):</u> Significant differences in weight occurred among planting configurations for boiler, small and medium sized bulbs. The strongest correlation with total marketable yield occurred with medium sized bulbs ($R = 0.8838$; $p = 0.0000$). There was a general trend that as plant population increased, boiler, small and medium bulb weight increased. Treatment #11 (15" rows, 1.5" plant = 22.5 inch^2/bulb) had the highest boiler weight (38.8 cwt/A), which was not significantly different than treatment #13 (7.5" rows, 3" plant spacing = 22.5 inch^2/bulb) or treatment #12 (15" row, 2" plant spacing = 30 inch^2/bulb), but was significantly higher than treatment #8 (7.5" rows, 4" plant spacing = 30 inch^2/bulb). All planting configurations with 45 inch^2/bulb or more had significantly less boiler weight than treatments #11, #12 and #13. Treatment #11 had significantly the highest small bulb weight than all other treatments (164 cwt/A). Planting configurations with 40 inch^2/bulb and greater had significantly less small bulb weight than the other treatments. Treatment #13 had the highest medium bulb weight (238 cwt/A) which was not significantly higher than treatment #11. Treatment #4 (15"

rows, 8” plant spacing = 120 inch^2/bulb) had the lowest medium bulb weight, which was not significantly different than planting configurations with 40 inch^2/bulb or more, except for treatment #9 (7.5” rows, 6” plant spacing = 45 inch^2/bulb). There were no significant differences in jumbo bulb weight, although there was a weak relationship that as plant population decreased jumbo weight increased.

For each of boiler, small and medium bulb weight, there was a consistent trend that within each row spacing (15”, 10” & 7.5”), weight decreased as plant spacing increased from 4” to 6” to 8”. Also within each plant spacing (4”, 6” & 8”), weight decreased as row spacing increased from 7.5” to 10” to 15”. No significant differences occurred between the two grower standards, although numerically, the 15” row spacing configuration had less boiler and higher medium weight, while the 10-20-10” row spacing configuration had higher jumbo weight. No significant differences occurred among the three planting configurations that had 60 inch^2/bulb.

These results for yield and bulb size distribution were similar to trends that we have found in previous studies despite the plant size and maturity results being opposite of our previous results. Our data suggests that plant spacing is a stronger predictor of yield and bulb size than row spacing or bulb area. It is also important to note that when greater than 40-50% of the total crop falls into the small and boiler bulb size classes that it can be challenging to market the entire crop, as medium and jumbo sized bulbs dominate the market.

<u>Bacterial Bulb Decay (Table 3):</u> Bacterial bulb decay 9 weeks after the onions were pulled from the field ranged from 1.3 to 16 cwt/A and 0.8 to 3.6% incidence and no significant differences occurred among planting configurations. Since decayed bulbs weigh less than healthy bulbs, instead of calculating percent rot on a per weight basis, it was calculated on a per bulb basis as incidence of bacterial bulb decay. There were no significant correlations between incidence of bacterial bulb decay and plant size, maturity, yield and bulb size distribution. There was no relationship between bacterial bulb decay and plant population. The highest incidence of bacterial bulb decay occurred in treatment #7 (10” rows, 8” plant spacing = 80 inch^2/bulb), while the lowest incidence of bacterial bulb decay occurred in treatment #13 (7.5” rows, 3” plant spacing = 22.5 inch^2/bulb). However the other planting configuration with 22.5 inch^2/bulb (treatment #11) and one of the 30 inch^2/bulb (treatment #8) had the forth and second highest incidence of bacterial bulb decay, respectively. The two planting configurations with the lowest plant populations (treatment # 3 & #4) had the second lowest incidence of bacterial bulb decay.

Of the two grower standards, treatment #1 (10-20” rows, 4” plant spacing) had twice the incidence of bacterial bulb decay (2.6%) than treatment #2 (15” rows, 4’ plant spacing). Of the three planting configurations with 60 inch^2/bulb, treatment #6 (10” rows, 6” plant spacing) and #10 (7.5” rows, 8” plant spacing) had 1.5x and 1.4x more bacterial bulb decay than treatment #2 (15” rows, 4” plant spacing). For the 4” and 6” plant spacing configurations, incidence of bacterial bulb decay increased as row spacing decreased from 15” to 10” to 7.5”. This trend is also the opposite of what we found in our studies with small-scale onion production. At 8” plant spacing, incidence of bacterial bulb decay was highest in the 10” row spacing by 2x and 5.5x than 7.5” and 15” row spacings, respectively. There was no difference in incidence of bacterial bulb decay between 4” and 6” plant spacing when the row spacing was 15”, 10” and 7.5”.

With such low levels of bacterial decay in this trial and no significant differences among treatments, we can’t make any definitive conclusions about the effect of plant and row spacing, and bulb area on bacterial bulb decay. In general, levels of bacterial bulb decay were low in New York, which was most likely caused by the very dry weather during the month of July.

Economic Return (Table 3): Total economic return was most strongly correlated to medium bulb weight (R=0.8177; p=0.0000) and jumbo bulb weight (R = 0.7198; p = 0.0000). Although there were no significant differences, there was a general trend that economic return increased as plant population increased. The highest return was $6,314/A in treatment #13 (7.5" rows, 3" plant spacing = 22.5 inch^2/bulb) while the lowest was $2,749 in treatment #7 (10" rows, 8" plant spacing = 80 inch^2/bulb). The grower standard with 10-20" row spacing returned $167 (=5%) more than the 15" row spacing configuration. Of the three treatments with 60 inch^2/bulb, treatment #10 (7.5" rows, 8" plant spacing) had the highest return ($4,029), which was $496 (= 14%) and $642 (= 19%) more than treatment #2 (grower standard; 15" rows, 4" plant spacing) and treatment #6 (10" rows, 6" plant spacing), respectively. There was a strong trend that within each row spacing, 15", 10" and 7.5", return decreased as plant spacing increased from 4" to 6" to 8". There was a very weak trend that at each plant spacing, 4", 6" and 8", return decreased as row spacing increased from 7.5" to 10" to 15".

Our yield and economic return data suggests that further investigation into planting configurations with 7.5" row spacing (= 7 rows per 5-foot bed) with wider plant spacing is warranted for both transplanted and direct seeded onions to increase bulb size and economic return. However, these narrow row planting configurations need to be studied under conditions of high bacterial disease pressure to ensure that larger yields are not conducive to increased losses from bacterial bulb decay. Repeating this study to see if our preliminary trends are consistent is certainly warranted. Provided repeated studies yield robust results regarding the relationship between plant and row spacing, and bulb area/plant population, the next steps will be to use the results of these studies to leverage additional funding to optimize and integrate this technique into an IPM approach. For example, reducing nitrogen fertility has also been shown to reduce bacterial disease in onions. But, if a grower were to increase his plant population and reduce his nitrogen rate to the extent that each component works best independently, there may not be enough nitrogen to support the increased plant population and yield could be compromised.

Project Locations:
The trial was conducted in a commercial onion field in Orleans County. This trial needs to be repeated before recommendations regarding altered planting configurations can be made to manage bacterial diseases of onions. If future results yield recommendations for managing bacterial diseases of onions, the impact of this study could be far-reaching across New York State as well as into Michigan, Wisconsin and Ontario and Quebec in Canada, where large-scale onion production occurs.

Samples of Sources Developed:

Table 1. Plant spacing configurations of onions, field trial, Albion, NY, 2012.

No.	Treatment (row & plant spacings)	No. rows per 5 ft wide bed	Row spacing (inch)	Plant Spacing (inch)	Area per bulb ($inch^2$)	Plant population (per acre)	No. plants per foot	No. plants per 5 x 5 ft plot
Transplant planting configurations:								
1	**Grower Standard 1**	**4**	**10-20-10[1]**	**4**	**40-80**	**104,544**	**3**	**60**
2	**Grower Standard 2**	**4**	**15**	**4**	**60**	**104,544**	**3**	**60**
3	Standard row, medium plant	4	15	6	90	69,696	2	40
4	Standard row, wide plant	4	15	8	120	55,272	1.5	30
5	Medium row, standard plant	5	10	4	40	156,816	3	75
6	Medium row, medium plant	5	10	6	60	104,544	2	50
7	Medium row, wide plant	5	10	8	80	78,411	1.5	37.5
8	Narrow row, standard plant	7	7.5	4	30	209,088	3	105
9	Narrow row, medium plant	7	7.5	6	45	139,392	2	70
10	Narrow row, wide plant	7	7.5	8	60	104,544	1.5	52.5
Direct Seed planting configurations:								
11	Standard row, narrow plant	4	15	1.5	22.5	278,784	8	160
12	**Grower Standard**	**4**	**15**	**2**	**30**	**209,088**	**6**	**120**
13	Very narrow row, wide plant	7	7.5	3	22.5	278,784	4	140

[1]4 rows per bed (5 feet wide) with 10" between row 1 & 2, 20" between row 2 & 3, and 10" between row 3 & 4.

Table 2. Effect of planting configuration on plant size of onions, field trial, Albion, NY, 2012.

Treatment				Plant height[1] (cm)		No. Leaves per plant		Neck Diameter (mm)	
No.	**Row spacing**	**Plant spacing**	**Bulb area (inch2)**	**June 13**	**July 13**	**June 13**	**July 13**	**June 13**	**July 13**
11.	15”	1.5”	22.5	26.8 a[2]	47.9	5.7 ab	7.8	7.1	8.8
12.	15”	2”	30	25.9 abc	49.2	5.5 bcd	7.8	7.4	9.1
2.[4]	15”	4”	60	24.6 cde	46.3	5.3 cd	7.9	7.1	9.9
3.	15”	6”	90	25.7 abc	46.9	5.5 bc	8.1	7.2	9.8
4.	15”	8”	120	25.1 bcd	48.6	5.2 de	7.8	7.2	10.1
1.[4]	10”-20”	4”	40-80	23.2 e	45.5	5.4 bcd	7.7	7.0	9.8
5.	10”	4”	40	24.6 cde	45.6	4.9 e	7.5	7.2	9.5
6.	10”	6”	60	23.8 de	45.6	5.2 cde	7.7	7.0	9.9
7.	10”	8”	80	24.7 cde	46.2	5.1 de	7.9	7.2	9.6
13.	7.5”	3”	22.5	25.5 abcd	48.7	5.9 a	8.1	7.9	9.4
8.	7.5”	4”	30	25.7 abc	46.6	5.5 bc	7.6	7.3	9.2
9.	7.5”	6”	45	24.2 cde	46.5	5.3 cd	7.4	7.2	9.3
10.	7.5”	8”	60	26.5 ab	47.3	5.4 bcd	7.8	7.7	9.5
			P Value (α=0.05):	***0.0008***	***NS[3]***	***0.0000***	***NS***	***NS***	***NS***

[1]Plant height of tallest leaf per plant. [2]Numbers in a column followed by the same letter are not significantly different, Fisher’s Protected LSD test, $p<0.05$. [3]NS: not significant, according to Fisher’s Protected LSD test, $p>0.05$. [4]Grower’s standard planting configuration: **2.)** 4 rows per bed (5 feet wide) evenly spaced = 15” row spacing; **1.)** 4 rows per bed (5 feet wide) with 10” between row 1 & 2, 20” between row 2 & 3, and 10” between row 3 & 4.

Table 3. Effect of planting configurations on onion maturity, yield, bulb size distribution and bacterial bulb decay, field trial, Albion, NY, 2012.

Treatment				% Target pop'n	Maturity	cwt/A	Bulb Size Distribution (cwt/A)				cwt/A	% bulb decay[1]	Total Return[5] ($/acre)
No.	Row spacing	Plant spacing	Bulb area ($inch^2$)		% Lodging (Aug 10)	Total Marketable Yield	Boiler (<1.75")	Small (1.75 – 2.25")	Medium (2.25 – 3")	Jumbo (>3")	Bacterial bulb decay		
11.	15"	1.5"	22.5	96 d[2]	66	440 a	38.8 a	164 a	180 ab	65	16.0	2.4	$6,053
12.	15"	2"	30	99 cd	52	340 ab	25.9 abc	107 b	140 bc	67	5.1	1.5	$4,802
2.[4]	15"	4"	60	99 bcd	61	232 bc	9.4 de	50 d	120 bcd	53	7.3	1.3	$3,533
3.	15"	6"	90	100 abcd	64	207 c	3.7 de	25 d	79 cd	89	1.3	1.3	$3,301
4.	15"	8"	120	106 a	77	167 c	3.5 e	20 d	62 d	81.5	2.6	1.3	$2,838
1.[4]	10"-20"	4"	40-60	102 abc	56	221 c	13.8 de	48 d	95 cd	64	6.6	2.6	$3,366
5.	10"	4"	40	98 cd	55	263 b	15.9 cd	60 cd	113 bcd	74	6.1	1.9	$3,989
6.	10"	6"	60	104 a	54	214 c	7.8 de	39 d	99 cd	68	6.3	1.9	$3,387
7.	10"	8"	80	104 ab	59	171 c	3.7 e	31.5 d	75.6 d	60	3.7	3.6	$2,749
13.	7.5"	3"	22.5	95 d	60	440 a	28.8 ab	114 b	238 a	60	3.1	0.8	$6,314
8.	7.5"	4"	30	99 bcd	43	329 ab	17.8 bcd	100 bc	168 b	44	14.1	3.2	$4,663
9.	7.5"	6"	45	103 abc	40	251 b	12.9 de	55 d	139 bc	44	10.5	3.2	$3,734
10.	7.5"	8"	60	105 a	66	248 b	7.3 de	41.6 d	102 cd	97	6.4	1.8	$4,029
	P Value (α=0.05):			***0.0010***	***NS***[3]	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***NS***	***NS***	***NS***	***NS***

[1]% bulb decay out of total number of bulbs at harvest. [2]Numbers in a column followed by the same letter are not significantly different according to Fisher's Protected LSD test, p<0.05. [3]**NS:** Not significant, according to Fisher's Protected LSD test, p>0.05. [4]Grower's standard planting configuration: **2.)** 4 rows per bed (5 feet wide) evenly spaced = 15" row spacing; **1.)** 4 rows per bed (5 feet wide) with 10" between row 1 & 2, 20" between row 2 & 3, and 10" between row 3 & 4. [5]2012 prices provided by grower cooperator for yellow cooking onions (per cwt): boilers - $6; small - $10; medium - $16; jumbo - $20.